STUDY OF IONOSPHERIC IRREGULARITIES OVER LOW-LATITUDE STATION VARANASI USING VHF SCINTILLATIONS

R. P. Patel [1], A. K. Singh [2], and R. P. Singh [1]

[1] *Atmospheric Research Laboratory, Physics Department, Banaras Hindu University, Varanasi-221005, India.*
Email: rppatel123@rediffmail.com, rampal@bhu.ac.in
[2] *Department of Physic, Maharaja College, V. K. S. University, Ara-802301, India.*
Email: abhay_s@rediffmail.com

ABSTRACT

The VHF amplitude scintillations recorded during January 1991 to December 1999 at Varanasi have been analyzed to study ionospheric irregularities during the quiet and disturbed conditions. The role of solar and geomagnetic activity on the enhancement and suppression of ionospheric irregularities during different seasons are clearly depicted. Derived spectral index ranges between –2 and –8 with mean value of 4. The characteristic length of these irregularities varies from 200 m to 800 m having drift velocity between 75 m/sec and 200 m/sec. The obtained results are discussed in the light of recent observations.

INTRODUCTION

The fluctuations in the ionospheric electron density, commonly known as irregularities, are generated on the bottom side of the post-sunset F-region over the magnetic equator by the nonlinear Rayleigh-Taylor instability mechanism [1]. The space-time variability of ionospheric irregularities are of serious concern to radio communications because these irregularities affect the amplitude and phase of satellite signals. Amplitude scintillations usually cause signals to fade below the average level. When the depth of the fading exceeds the fade margin of a receiver; the signal is buried in noise and signal loss and cycle slips are encountered [2]. Hence, in order to provide support to operational communication/navigation systems, the magnitudes of amplitude and phase scintillations and the temporal structures of scintillations need to be specified.

In this paper, we present some results of 244 MHz amplitude scintillation measurements during the period January 1991 to December 1999 at a low latitude station Varanasi (geom.. lat. 14^0 $55^/$ N), which is situated near the northern crest of the equatorial anomaly zone. We have examined the seasonal variation of the scintillation activity and showed that both the seasonal pattern and the level of scintillations are controlled by solar activity. The effect of magnetic activity on the occurrence of scintillations is also studied. Some statistical features of overhead ionospheric irregularities such as velocity, scale size, time duration and power spectrum have been also determined.

EXPERIMENTAL DATA

The amplitude scintillations of the 244 MHz signal radiated from the geo-stationary satellite FLEETSAT situated at 73^0 E longitude were continuously monitored at Varanasi using a fixed frequency, VHF receiver and a strip chart recorder. In addition to the normal chart recorder, data were also recorded digitally, at the sampling rate of 10 Hz, on a few nights. The scintillation index in dB has been scaled manually every 15 min by measuring peak to peak $P_{max} – P_{min}$ excursion in dB and using a calibration chart and conversion chart [3]. The scintillation data are tabulated for each 15 min to count the number of events per hour and hence to evaluate the occurrence rate.

RESULTS AND DISCUSSIONS

The available data beginning from Jan. 1991 to Dec. 1999 shows that at Varanasi, scintillations are observed mostly in the nighttime and predominantly during pre-midnight period in small patches with duration < 30 minutes [4]. The intensity distribution in the scintillations observed during the above is

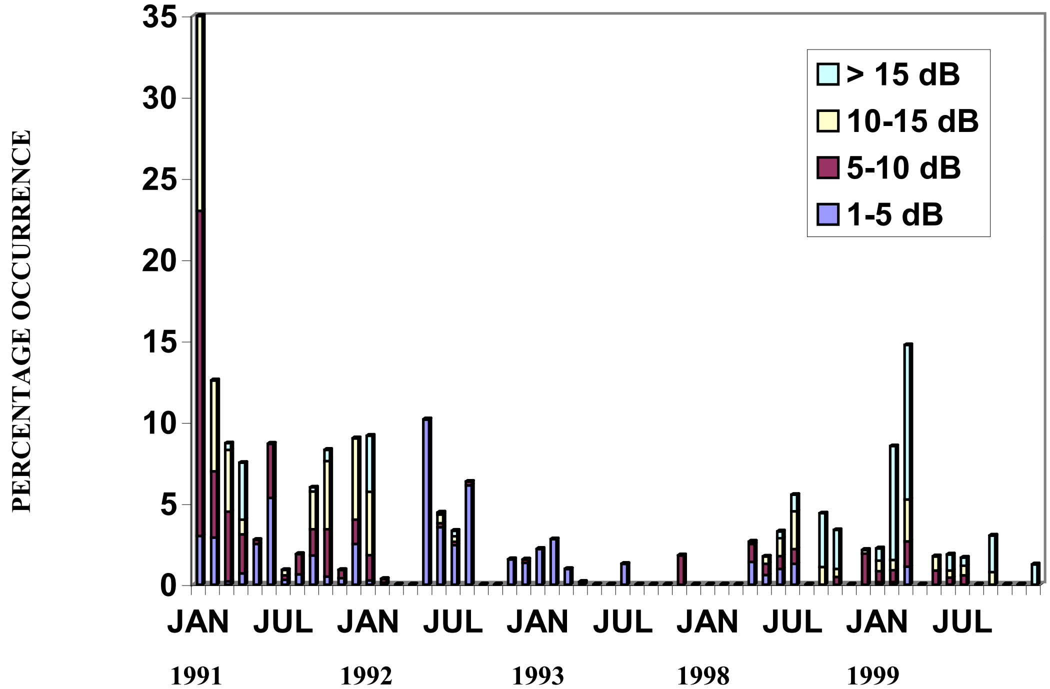

Fig. 1 Month-to-month variation of percentage occurrence of fade depth indices in dB for night time scintillations.

shown in "Fig. 1". Different colors indicates fade depth indices in dB ranging from 1 dB to 20 dB. Fade depth during the summer months is usually less than 5 dB, where as during the winter and equinox months, it varies between 5 and 15 dB. Fade depth greater than 15 dB were observed in April and October 1991 and were more frequent during 1998 and 1999. The relatively intense and faster fade rate observed before midnight at Varanasi could be of equatorial origin during winter and equinox seasons [5]. Comparatively week, slow and short duration scintillations seen during summer could have a local/mid-latitude/equatorial origin [6].

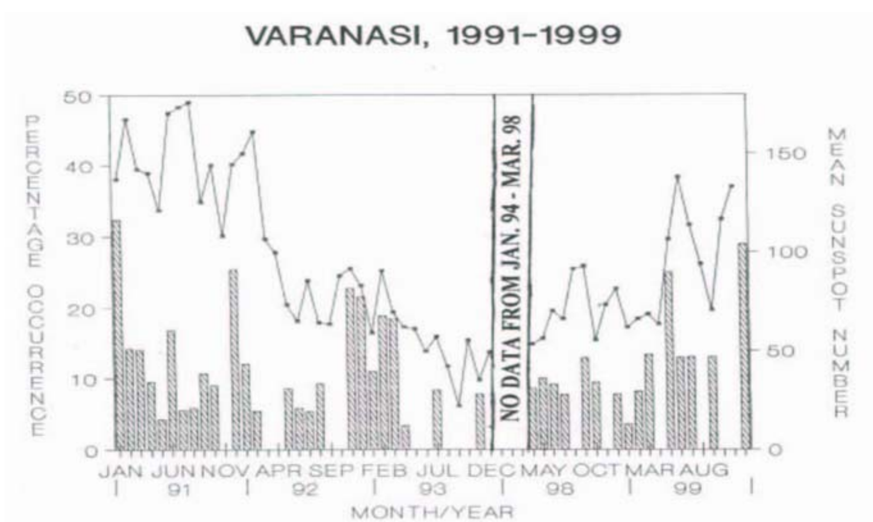

Fig.2 Month-to-month variation of mean percentage occurrence of scintillation and sun spot numbers for the years January 1991 to December 1999.

The month-to-month variation of the mean percentage occurrence of scintillation and the mean sunspot number for the years 1991-1993 and 1998-1999 is shown in "Fig. 2". During equinox and winter months, scintillation activity increased with increased sunspot number, whereas during the summer months no significant change in the occurrence of scintillations is seen with a change in solar activity.

More meaningful information about the irregularities can be derived from digital data. These are scintillation index S_4, auto-correlation function and power spectra which contain information about relative power of irregularities in different spatial scales. Twenty five samples of digital scintillation records have been analyzed for estimating power spectra. The spectral slopes between 0.1 Hz – 1 Hz have been computed for all the 25 samples and it is observed that the spectral index values range between –2 and –8 with a mean value of –4. From the weak scintillation theory for a phase changing screen models the velocity of the scintillation producing structures is given as [7], $V = (\lambda z)^{1/2} f_{min}$, where z is the height of the phase screen, λ is the signal wavelength and f_{min} is the first Fresnel minima of the given spectra. The velocity of irregularities computed for all the 25 samples is found to lie between 75 m/sec and 200 m/sec.

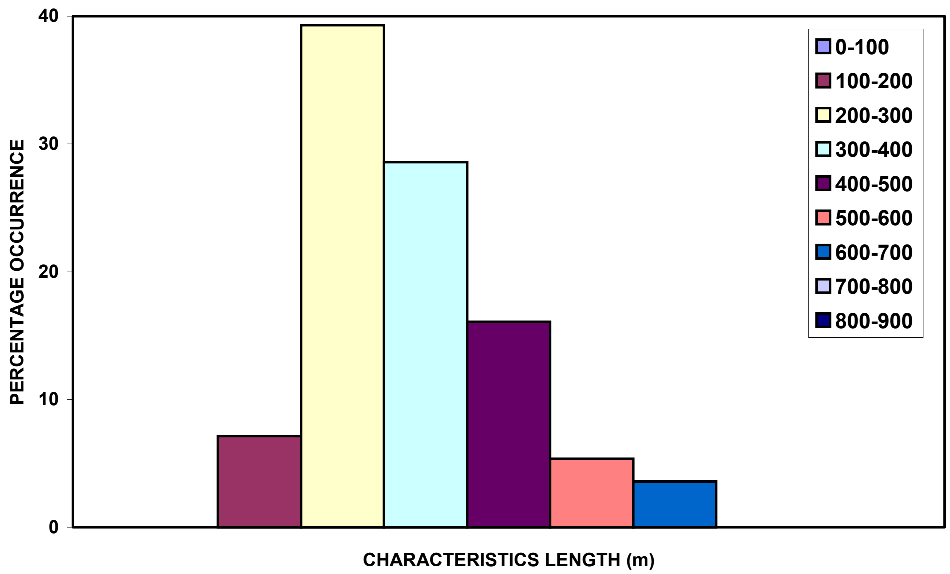

Fig.3 Histograms of percentage occurrence of characteristic lengths of over head irregularities during 1991-1999.

The size of the irregularities are determined from the auto-correlation function of the recorded scintillations. The size of the irregularities is equal to the distance at which the auto-correlation falls to 0.5 [8]. Considering average drift velocity of irregularities V = 100 m/sec, we have computed half-correlation time and characteristic length for 50 samples and observed that the characteristic length varies between 200 m to 800 m. A histogram of percentage occurrence of characteristic length of over head irregularities during 1991 and 1999 is shown in "Fig. 3", which belongs to intermediate scale range with occurrence peak around 300 km.

The fact that the scintillations at Varanasi occur usually in patches, while scintillations at and near the equatorial stations are more continuous [9], supports the idea of upwelling of plasma irregularities in the equatorial F-region around post sunset and then subsequent moving towards low-latitude and breaking into smaller patches [10]. The occurrence of scintillation is controlled by solar activity. The increase of solar activity normally increases the depth of scintillation. Whereas the increase of magnetic activity suppresses the occurrence of scintillation [11]. Spectral analysis of observed amplitude fluctuations have shown that the electron density irregularities in the ionosphere may be characterized by a power law spectrum and the slop of the spectrum is different for different scale size ranges. Present observations in the scale size range between 100 m and 1000 m indicate a mean spectral index value of –4, which is in close agreement with the insitu observed value of –4 at

SHAR [12]. The velocity of irregularities computed from scintillation data of Varanasi lies between 75 and 200 m/sec which is in good agreement to that reported by Pathak et al [13] from Rajkot data.

SUMMARY

The salient features of the present study are summarized as follows:

1. The scintillation occur mostly in patches and the patch duration generally being < 30 minutes.
2. The increase of solar activity normally increases the occurrence of scintillation where as, the increase of magnetic activity suppresses the occurrence of scintillation.
3. The spectral index of overhead plasma irregularities generally range between –2 and –8 with a mean value of –4 for intermediate scale range.
4. Drift velocity and characteristics length of irregularities varies between 75 m/sec and 200 m/sec, and 200 m and 800 m respectively.

ACKNOWLEDGEMENTS

The work is supported by the Department of Science and Technology, New Delhi under SERC project. R. P. Patel is thankful to CSIR, New Delhi for the award of Research Associateship.

REFERENCES

[1] M. C. Kelley, *The Earth's Ionosphere: Plasma Physics and Electrodynamics*, Academic, San Diego, Calif.nia, 1989.
[2] S. Basu, K. M. Groves, Su. Basu and P. J. Sultan, "Specifications and forcasting of scintillations in communication/navigation links: Current status and future plans", *J. Atmos. Solar Terr. Phys.,* Vol.4, pp. 1745, 2002.
[3] H. E. Whitney, J. Aarons and C. Malik, "A proposed index for measuring ionospheric scintillations", *Planet. Space Sci.*, Vol.17, pp. 1069-1073, 1969.
[4] A. K. Singh and R. P. Singh, "Observations and modeling of nocturnal ionospheric irregularities in low latitude region", *J. Geomag. Geoelectr.*, Vol.49, pp. 1115-1127, 1997.
[5] S. Kumar and A. K. Gwal, "VHF ionospheric scintillations near the equatorial anomaly crest: solar and magnetic activity effect", *J. Atmos. Solar Terr. Phys.*, Vol.62, pp. 157-169, 2000.
[6] S. K. Chakraborty, A. Das Gupta, S. Ray and S. Banerjee, "Long term observations of VHF scintillation and total electron content near the crest of the equatorial anomaly in the Indian longitude zone", *Radio Science*, Vol.34, pp. 241-255, 1999.
[7] S. J. Franke and C. H. Liu, "Observations and modeling of multi-frequency VHF and GHz scintillation in the equatorial region", *J. Geophys. Res.*, Vol. 88, pp. 7075, 1983.
[8] S. R. Khastgir and R. N. Singh, "The size of the moving irregularities in the F-region and the spread angle of the radio waves scattered from them", *J. Atmos. Terr. Phys.*, Vol.18, pp. 123, 1960.
[9] H. Chandra, et al., "Coordinated multistation VHF scintillation observations in India during March-April 1991", *Ind. J. Radio & Space Physics*, Vol.22, pp. 69-81, 1993.
[10] J. Aarons, "Equatotrial F-layer irregularity patches at anomaly latitudes", *J. Atmos. Terr. Phys*., Vol.47, pp. 875-883, 1985.
[11] R. P. Singh, R. P. Patel and A. K. Singh, "Effect of solar and magnetic activity on VHF scintillations near the equatorial anomaly crest", *Ann. Geophysicae*, Vol.22, pp. 2849-2860, 2004.
[12] S. Prakash, S. Pal and H. Chandra, "In-situ studies of equatorial spread F over SHAR-steep gradients in the bottomside F-region and transitional wavelength results", *J. Atmos. Terr. Phys.*, Vol.53, pp. 977, 1991.
[13] K. N. Pathak, R. D. Jivrajani, H. P. Joshi and K. N. Iyer, "Characteristics of VHF scintillations in the equatorial anomaly crest region in India", *Ann. Geophys.*, Vol.13, pp. 730, 1995.